The upwelling velocity in the Pacific near San Diego was thus estimated to be about 25 meters per month during the summer, and the rate of penetration of solar radiation thus found was in good agreement with results obtained by independent methods.

By applying the same mechanism of downward diffusion to the distribution of salinity, and combining the resulting equations with those pertaining to temperature, the surface cooling due to evaporation and other causes can be estimated separately. This means of determining the rate of evaporation from the ocean by means of serial observations of temperature and salinity between the surface and the hundred-meter level, while theoretically possible, has not yet been applied. An approximate estimate of ocean evaporation from the rate of surface cooling can be made by supplementing the serial observation with observations on an evaporating pan containing sea water.

Numerical or graphical integration of the equations after the various physical magnitudes have been found as indicated above should reproduce the subsequent changes in temperatures and salinities from their initial values. If the upwelling velocity is not included, integration should yield "normal" values; that is, values of temperature and salinity to be expected in the absence of a general flow of the water.

A NEW ANALYSIS OF THE SUN SPOT NUMBERS

By DINSMORE ALTER

[University of Kansas, Lawrence, Kans., November 16, 1928]

During the past 10 years the writer has worked a great deal with analyses of data and has spent much time on the sun spot numbers. However, except for one brief paper on the 11-year means (**1a**), read before the Astronomical Society in 1921, he obtained no results worthy of publication by any of the older methods.

With the development of the equations used in the correlation periodogram (**1b**) last year it seemed worth while once more to try the problem. All previous analyses had depended on repetitions of a sine curve of assumed period, the best of these being those made by the Schuster method. For such a method the number of data was far too small, either to prove the existence or nonexistence of fairly constant periodicities (**1c**). The new method, however, using not only such a curve but all its harmonics simultaneously, promised to require less data for a decision. Accordingly a thorough analysis was made. Since the complete method was published in this journal it will not be developed here.

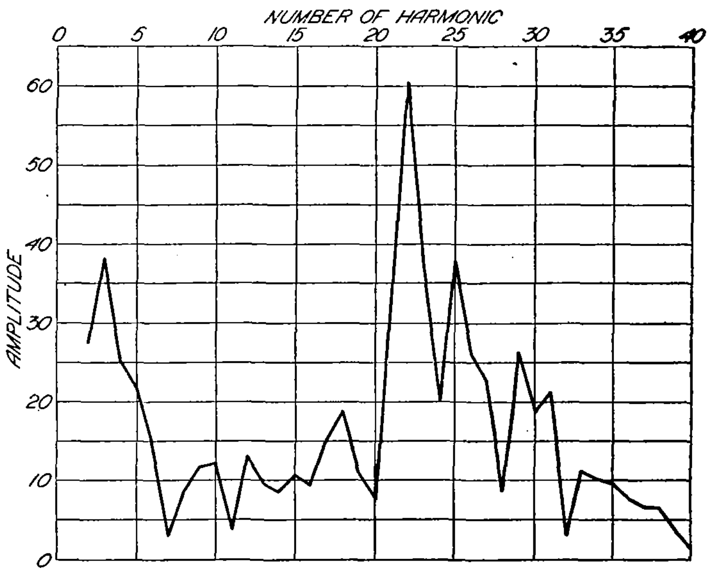
The unsmoothed Wolf-Wolfer numbers for the years 1749–1926 were formed into 6-month means, giving 356 data. The periodogram was computed using logs, varying by 6-month steps, from 12½ to 142½ years for the separate correlations. The number of pairs of data used therefore, in computing each correlation coefficient ranged from 331 down to 71. Beyond the latter number but little accuracy would have been secured. The periodogram is reproduced as Figure 1.

Naturally the first feature of the periodogram to strike the eye is the series of crests at a little more than 11-year intervals. Examination will show, however, that their intervals do not even approximate the generally accepted value of 11⅛ years but average 11.37 years and are quite consistent in grouping around this figure. In other words, although the number of maxima and minima usually considered by investigators to be principal ones is such as to give approximately an 11⅛-year mean, the shape of the curve is such that the best correlations occur after intervals of more than 11⅓ years. This checks with the long value assumed by Mount Wilson.

The next significant feature of the periodogram is the variation in amplitude of its swing between minimum and maximum. It reaches a minimum amplitude at about 33 years, a maximum at about 65 or 70, and a very pronounced minimum at about 126 years. The curve as a whole also swings about the zero line from a minimum at approximately 40 years to a maximum at about 85 and another minimum near 126. The latter feature is evidently due to a cycle (either accidental or significant) of about 85 years.

The variation in amplitude is far too great to be accidental. Perhaps we have no exact periodicity, but a tendency toward lengthening and shortening of the cycle such tendencies persisting through considerable number of years. However, the changes resemble so closely the familiar best pattern made by superimposed periodicities that it is worthwhile investigating the hypothesis that they actually are such.

The amplitude has decreased nearly to zero at 126 years. Such a pattern could come only through the superposition of periodicities, which are harmonics of



No. 1. Correlation periodogram of sun spot numbers

twice this period. If only such a primary and a 126-year period existed, the pattern would have shown a steady decrease to zero at this point instead of the maximum at 85 years. It is obviously easy to find three harmonics of 252 years which would give the secondary and primary minima and the maximum observed. This was done early in the investigation, but the more logical plan is to compute all the harmonics of 252 years and find the amplitude of each. *One thing which the pattern definitely tells us is that, if the sun spot variation is the result of superposition of fairly constant periodicities, any large ones of length less than a century must be harmonics of approximately 252 years.*

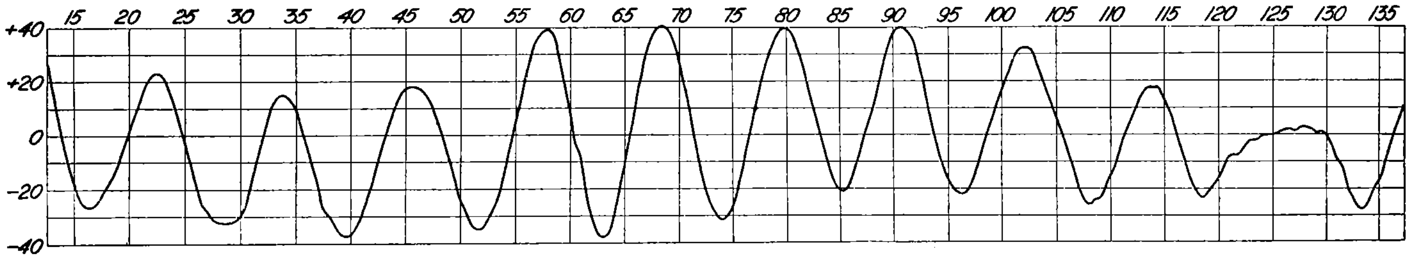
These harmonics of 252 years were, therefore, all computed beginning with the second of period 126 years and ending with the fortieth of period 6.3 years. The data are reproduced as Figure 2, where the ordinates are the amplitudes, expressed as percentages of the mean sun-spot number. They vary in amplitude from practically zero for the fortieth to 61 per cent for the twenty-second. The distribution of large amplitudes does not follow, in the least, that expected by the error law. Since the basic period is 252 years, instead of the 178 for which we have data, adjoining periods are not entirely independent, though nearly so. The amplitudes are all greater than 20 per cent through the fifth, then all are less than this value (with the exception of the eighteenth far less) through the twentieth. From here through the thirty-first with two exceptions all are greater than 20 per cent and from there on all are far less. Whether we have exact periodicities or not, such a distribution can not be accidental.

It will be interesting to see whether we have any known physical phenomena which would reproduce the frequency pattern found here. Prefacing the analogy by the statement that the author has no belief in an electrical explanation of the sun spot variation, he wishes to use one to illustrate exactly what has been found. Let us construct a coil of such capacity and inductance that it is tuned to oscillate over a rather broad band of frequencies, say between one-twenty-first and one-thirty-first of a second. Let us impose on this coil an electrical impulse each second, of such nature that the harmonics decrease in amplitude as they decrease in length of period. Such impulses are easy to produce. The longer harmonics, having great amplitude, will be found as forced surges in the coil, despite its damping qualities. Soon the amplitude of these surges will decrease to negligible amounts and none of large amplitude will be found until we reach the band for which the coil is tuned. Here again we will find surges of large amplitude and, when the band is past, the amplitudes will rapidly decrease almost to zero. Periodicities other than harmonics of the primary surge will not be found. We have then an actual case of frequency distribution similar to that *apparently* found in the sun spot data.

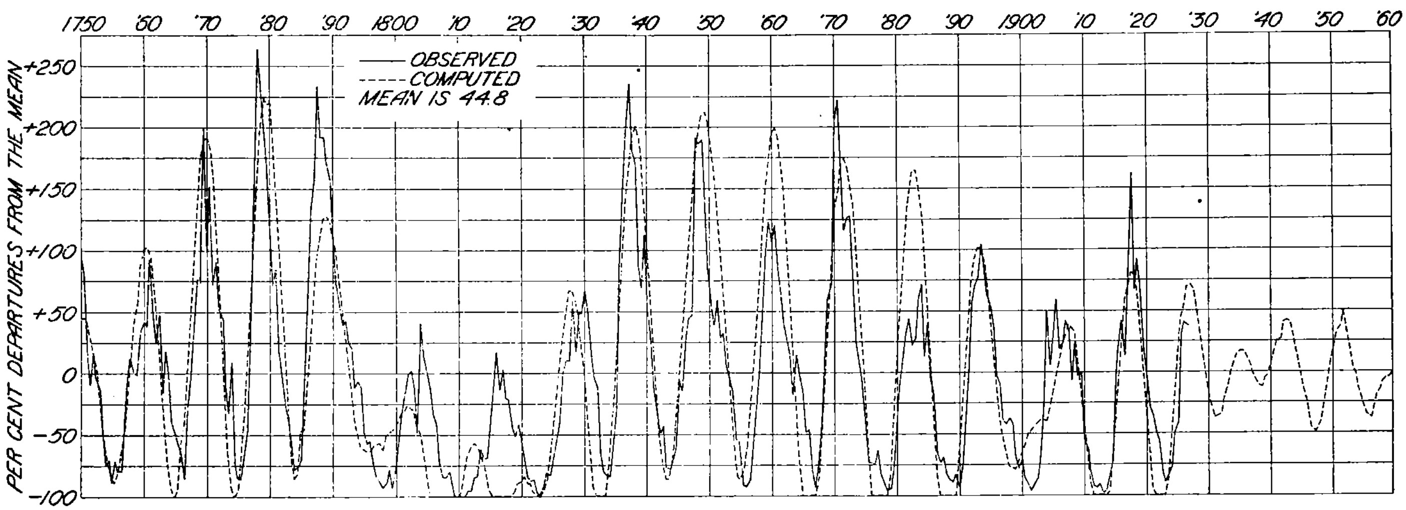
All harmonics of amplitude greater than 20 per cent have been added together to reproduce the past history of the variations and to extrapolate for test purposes. Of course, inclusion of smaller terms would have increased the accuracy of the representation of the past as closely as might be desired. Such a gain would have had little advantage, for, if it should prove to be true that the large periodicities chosen are substantially real, they must give enough of a correlation between ephemeris and future observation to demonstrate their validity without the use of smaller ones, even though such might also be real. If these be real, or approximately so, accurate prediction by means of all possible periodicities would belong to later work. Figure 3 gives this representation.

Fortunately, for our test purposes, the ephemeris shows, in the immediate future, very small oscillations similar to those at the beginning of the last century, except that now, instead of being superposed on a minimum of the general progression they oscillate about the mean. *The author does not predict that the ephemeris will be followed.* He merely claims that *if* approximately constant periodicities do exist they must be the series found. His own opinion regarding such will be based on the observations of the next 10 or 15 years. If there are no very pronounced maxima or minima, he will accept them as real, otherwise believe the phenomenon to be nonperiodic.

The inaccuracy of the first three-quarters of a century of data must have to some extent vitiated amplitudes and



No. 2. Amplitudes of sun spot terms



No. 3. Sun spot representation, using 126, 84, 68 . . . terms

phases of such periods. It is believed, therefore, that beyond the possible demonstration of their existence, little can be done to secure accurate ephemerides until at least another half century of data are secured.

The writer's studies are primarily concerned with probabilities of observed departures from the error law, not with physical explanations of results found. However, he wishes to suggest very tentatively an explanation. Various writers have, during the past 30 years, urged the planetary tides as an explanation of sun spots. Most noteworthy of these is an early paper by E. W. Brown (2), using the tides of Jupiter and Saturn. With these he gave an excellent representation of the past epochs of maxima and minima. An ephemeris computed for the 30 years since his paper was published is almost perfect in locating epochs.

The tides have always seemed an impossible explanation on account of their feebleness in comparison with the sun's gravitational field. However, the recent study of radiation pressure and of the solar spectrum have proved an almost perfect balance of forces in the solar atmosphere. This being the case small tidal effects may possibly produce large results.

To test this possibility, an examination was made to see whether there is any unique relationship of the planetary periods to the assumed primary impulse period of 252 years. Exact multiples and half multiples of their periods must be considered, since, except for eccentricity effects, the latter give the same tidal effects as the former. So far as probabilities are concerned the deviations of the nearest multiples from a common multiple may be as great as 25 per cent of a planet's period. If there is much less average deviation than half this amount, there is a straw of evidence in favor of the hypothesis.

Planet	Period	Multiple factor	Product	Per cent deviation in terms of planet's period
Jupiter	11.862	21	249.10	4.8
Saturn	29.458	8½	250.39	2.4
Uranus	84.015	3	252.04	2.8
Neptune	164.788	1½	247.16	1.5
Mean			249.67	

In every case the percentage deviation is found to be very small. This 250-year multiple is the only one to be found for these planets. The uncertainty of our 252-year period is greater than the difference from this mean. Though one would not wish to claim anything for the coincidence, it certainly is one to be borne in mind.

The writer wishes to acknowledge the aid of a grant from the research committee of the University of Kansas, under which he engaged Mr. James Edson to do the majority of the computing.

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THE PERIODS OF SOLAR AND TERRESTRIAL PHENOMENA [1]

By Prof. H. FRITZ

[Translated by W. W. Reed]

In the past decades there have appeared numerous papers on the periodic phenomena whose changes show more or less marked agreement with the periodic change in solar activity as it is most readily traceable in the changing frequency of sun spots. A similar change together with apparent relation, unexplainable or not directly explainable, between processes on the earth and processes on the sun can not be astonishing since the manifestation of energy, all animate or inamimate nature on the earth, is subject to energy radiated from the sun to the planet. The earth provides the matter, the sun supplies the energy. In contrast to the supply of energy from the sun, that from the interior of the earth, that radiated to the earth from the stars, and that reflected to the earth from the moon fade into nothingness. The moon acts most effectively through the attraction exerted on the earth and its constituent parts.

Inevitably every variation in solar activity must be reflected in terrestrial processes, although because of the general constitution of the earth, the variability frequently remains more or less out of sight, becomes not directly observable, or, it may be, escapes all observation due to compensation by other forces or effects. If, for example, with increasing solar radiation more water evaporates from the sea and, with the condensation of water vapor in the higher strata of the atmosphere, the liberated latent heat rises immediately to higher regions and into space, and at the same time insolation undergoes greater depletion on account of the greater amount of water vapor in the atmosphere, then even rather large differences in radiation of heat by the sun will be without influence on our measuring instruments and will no longer be shown by them. This single example will serve as well as many.

If there exist in the different phenomena of the earth periodic changes dependent on solar activity, then they can not be limited to a few decades; they must be present, on the contrary, in the oldest observations available at the present. In the contrary case one would be permitted to apply not entirely without reason the conventional word "accident."

Unfortunately, research extending far into the past is possible only in a restricted way; most of the useful data relative to the different kinds of phenomena are very recent.

Because of its definitely decided periodicity, its uniqueness, and its awesomeness, one terrestrial phenomenon can

[1] Astronomers and meteorologists appear to be but little aware of the general intrinsic value of the work done by Prof. H. Fritz which culminated in *Die Perioden solarer und terrestricher Erscheinungen*, published in *Vierteljahrschrift der Naturforschenden Gesellschaft in Zurich, Heft* 1, 1893.

As this publication is not accessible to many American students its translation and republication in the MONTHLY WEATHER REVIEW seems to be particularly appropriate at the present time when various authorities are seeking to establish indirect correlations between solar activity and features of weather sequence on the earth. It is a pleasure, therefore, to commend to the careful attention of the readers of the REVIEW Mr. Reed's translation of Professor Fritz's paper, more particularly with reference to the data and final tables of the epochs of the maxima of the 11-year cycle, which, with the modern tables of Wolfer, cover a total range of 17 and 34 years. The author's discussion of long periods and the possible causes of sun spots must stand on its own merits.—*C. F. Marvin.*